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ABSTRACT

This paper presents a World Wide Web-based infrastructure for cooperation between many different parties. The infrastructure is designed for Web-based competitions involving an editorial board, designers of assignments or events, evaluators, different organizational layers, and contestants. Web-CS is entirely Web-based: all the communication between the cooperating parties is achieved through communicating Web-browsers and Web-servers (augmented with Java-applets on the client side and a database system on the server side). The first section of the paper introduces the organizational structure of Web-based competitions in general. The second section describes the Hungarian KoMaL (Kozepiskolai Matematikai es Fizikai Lapok, i.e., a mathematical and physical journal for secondary schools) competition, the requirements for Web-CS, and comparable systems. The third section presents the Web-CS architecture, including system components, basic module structure, and document formats and file-uploading. (Author/MES)

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Web-CS: Infrastructure for Web-based Competitions

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Abstract: Most cooperative environments that have been developed for the Web are designed for groups of people with "equal rights" working together on a task, possibly supervised by a single level of administrative authority. We present a Web-based infrastructure for cooperation between many different parties. The infrastructure is designed for Web-based competitions, involving an editorial board, designers of assignments or events, evaluators, different organizational layers, and of course contestants.
Web-CS is entirely Web-based: all the communication between the cooperating parties is achieved through communicating Web-browsers and Web-servers (augmented with Java-applets on the client side and a database system on the server side). This paper presents the global architecture of Web-CS and its implementation, which is currently being tried out in Hungary and in The Netherlands.

1. Introduction

Internet and its most prominent application: World Wide Web are becoming a part of the daily life of a growing part of the population (in highly developed countries). More and more professional and social activities that are centered around knowledge, information, or both are being supported by Internet technology. Teleconferencing hard- and software (for an example application see [LFL]), shared workspaces, and other Internet-based CSCW tools [BSCW, DReSS] mostly aim at supporting small groups of people who are on the same level of an organization's hierarchy. There may be supervision by a single higher level of authority (the "boss" or the teacher [BKPW]), who in theory has more rights than his associates, but who often needs the help of a system administator to actually use these rights. (Organizational rights often do not translate to information system rights.)
Applications or frameworks are still lacking for supporting activities in which many different parties are involved, each with different *rights*. Large *competitions* involve such a variety of parties. This paper presents a Web-based version of the Hungarian KöMaL competition. Competitions in different kinds of games, physical and intellectual sports, music and sciences are all organized in a similar way. The exact organization of KöMaL is described in Section 2. Generally speaking such competitions are organized according to the following scheme:

- There is an *editorial or supervisory board* that "organizes" the competition.
  - It decides which "organizations" may participate in the competition. Such organizations can be local game or sports clubs, schools, etc. Participating organizations are responsible for entering individual contestants into the competition.
  - It determines categories of contestants. It designs rules to determine in which category a contestant should be entered. The rules may use age, skill level, sex, etc.
  - It determines which "events" will take place, fixes dates or chooses assignments or quizzes, etc.
  - It may appoint referees (or judges).
  - It collects results and publishes overviews, on a daily, weekly, monthly or yearly basis.
  - It has the final authority to overrule questionable decisions of referees, or to change the rules of the competition.
- Participating organizations appoint *delegates* who enter contestants into the competition (or who approve applications of contestants). While this is not always visible in "real world" competitions, it is essential in a Web-based competition.
- *Designers* or *local organizers* propose *events* to the board. Examples of events are a chess or bridge tournament, or assignments and problems for a science competition. The board decides on the acceptance of such events.
- *Referees* (or judges or evaluators) determine the results of events. They are appointed by the board.

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- *Interested third parties* (the press, the public) wish to view results.

Such a competition involves several layers of authority and responsibility. This hierarchical structure is the basis for keeping the whole competition *honest* and *fair*. If, for instance, contestants could enter themselves into the competition without going through an approval procedure, they might wish to enter into a "lower" category in order to have a better chance of winning.

The Web-based competition system presented in this paper is aimed at competitions that deal only with knowledge or information. The *events* are assignments or problems that are distributed through a Web-site. Contestants submit *solutions* to the editorial board who appoints *evaluators* to score these submissions.

The paper is organized as follows: Section 2 describes KöMaL, the paper-based competition that was brought on-line through our Web-based competition platform. Section 3 gives an overview of the architecture of Web-CS. It also describes some design details of essential components. Section 4 presents the current state of the project and its past and future developments.

2. The KöMaL competition: requirements for Web-CS

KöMaL stands for the Hungarian '**K**özépiskolai **M**atematikai és Fizikai **L**apok'. It is a Mathematical and Physical Journal for Secondary Schools. It is published monthly by the János Bolyai Mathematical Society and the Loránd Eötvös Physical Society.

2.1 Current Competition

The competition is centered around *exercises* or *problems*. Exercises are invented by *designers*, who send them to the KöMaL *editorial board*. An exercise is awarded a *level*, indicating the level of the students (third year, fourth year) for whom the problem was designed. The board makes a selection from the available exercises and publishes them in the journal, together with the results of earlier competition rounds. Each month about 20 mathematics and 10 physics exercises are published. An exercise that appears in the journal has an associated deadline, before which solutions must be received by the editorial board.

The students read the journal and formulate answers to the problems. They submit their solutions to the KöMaL-office. There the solutions are sorted by problem and distributed over a number of *evaluators*. Evaluators can specify their preference for a particular problem to the editorial board. The evaluators check the solutions they get assigned for correctness, "correct" them and give a grade. The corrected solutions and grades are sent back to the editorial board, who check them, and who may change grades if deemed necessary. The grades are entered into a computerized information system. The corrected solutions are sent back to the students. The evaluators recommend the best solutions for publication in a later edition of the journal. At the end of the term for the monthly competition round, the results are printed out and published. The competition takes one school year (nine issues and sets of problems). The student with the highest total score wins the yearly competition (for his or her level).

There is a separate competition for mathematics and for physics. The published results contain scores per student and per school. These results are not only printed in the journal but also published on the KöMaL home-page, at http://komal.elte.hu/. It is possible to review the results of the previous competitions, and to see the exercises and assignments of the current competition round.

KöMaL has already entered the digital era: students are allowed to submit solutions by e-mail, in Microsoft Word, LaTeX, Postscript or plain ASCII format. The solutions are printed at the KöMaL office, and sent to evaluators through paper mail.

The competition at present comprises seven, not necessarily disjoint, groups of users:

- **students**: they subscribe to the competition (subject to approval by a teacher) and submit solutions to the problems that are published in the magazine.
- **evaluators** (or correctors): they subscribe to certain problems, obtain a set of solutions for those problems (shortly after the deadline for submission) and correct and grade the solutions before a certain date.
- **editorial board**: this board consists of the publishers of KöMaL, who are responsible for the correctness of the contents of the magazine. The board selects the exercises to be published from the proposals sent in by the designers (see below). Board members can check the work of the evaluators and have the right to alter the grades. The board keeps track of the competition results and publishes this information .
- **designers**: they submit proposals for exercises and assignments to the board.

- **schools**: a school requests to take part in the competition. The school delegates its rights to a number of teachers.
- **teachers**: a teacher approves the application of students to enter the competition. He or she ensures that students are entered at the appropriate level.
- **third parties**: everybody who takes an interest in the competition: the public and the government who sponsors the competition. This group is not actually involved in the competition itself, but is interested in information about it.

As can be seen from the description above, the information flow associated with the competition involves a fair number of parties, each with different rights and responsibilities.

2.2 Requirements for Web-CS.

The aim of Web-CS is to provide a *fool-proof* infrastructure for Web-based competitions. By this we mean that the interaction between all the different parties and the Web-CS system should be uniform and simple to install and to use. The reasons are:

- Some (maybe all) parties involved in a Web-competition may have limited experience with computers or Internet tools.
- The parties involved in a competition may overlap. Many designers are also evaluators, and some of them are also teachers. The user-interface for these parties should be very similar.

Students may be working on problems and interact with Web-CS at home or at school. Therefore:

- The system should not require participants to have a permanent Internet-connection or to be connected for long periods of time.
- The system should not depend on a user always connecting from the same computer. Thus, the well-known "Cookie" mechanism cannot be used.

A *generic* competition system should be suitable for problems and solutions that are in very different formats. A mathematics competition involves formulas in questions and answers; a physics or biology competition may involve pictures and drawings; a computer science competition may involve the submission of program code. As a result:

- The published assignments may need a presentation format that is richer than the plain HTML-with-images style of the Web. All participants need to have a viewer for the chosen presentation format(s).
- Students need to be able to use a powerful document creation tool for writing their solutions. (Plain text and images are not sufficient.)
- Evaluators need viewer(s) for every document format which students are allowed to use in their submissions.

Most of the board's work should be automated:

- Problems should have unique identifiers.
- Solutions should have unique identifiers as well as the identifier of the problem they address.
- The distribution of solutions over evaluators should be automatic.
- The approval (and possible modification) of grades by board members should be easy.
- Approved grades should be published automatically and the corrected assignments sent back to the students.
- The scores should be published automatically, both monthly (which is the frequency of publication of the KöMaL journal) and yearly.

Students are eager to win, sometimes at the expense of others. Therefore the system should offer a number of security features to avoid cheating:

- Each participant in the system should have a distinct username and password. (An exception is the "public" who needs no password for viewing publicized information such as assignments and scores.
- Users must identify their "role" (e.g. teacher, designer, evaluator). Each role has associated *rights*. Users must not be able to perform tasks associated with a different role, or to select a role they are not allowed playing.
- Sensitive data, including passwords and solutions that are being submitted, should be communicated in encrypted form to prevent snooping attacks.
- The communication should be tamper-proof. A solution submitted by a student should arrive at the KöMaL site unaltered, and should also arrive at the evaluator's computer unaltered. Grades assigned by an evaluator should arrive at the KöMaL site unaltered.
- The KöMaL site should be well protected. Only board members should be able to access the database with grades directly, and be able to modify grades.
- Submission of (previously prepared) solutions should be possible without the solution being displayed on the student's computer screen.

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The Web-CS software is intended for multiple applications.

- The presentation of the whole Web-site and the entire communication should be possible in the native language of the students. Since applications in Hungary and in The Netherlands were envisaged from the start, this means that the software must be language-independent.
- Some competitions may have a slightly different organization. The software needs to be adaptable to local situations. E.g., some organizations may require that students are entered into the competition by their teacher, while others may let students register themselves but ask teachers for approval afterwards.

A final requirement is availability.

- Web-CS should be able to handle a high volume of requests for assignments. It is expected that when new assignments are published many students will be eager to view and download the new assignments quickly.
- The submission and evaluation process is more spread out in time. Currently KöMaL receives and grades around 50.000 solutions (to about 300 problems) each year. Processing these data (and generating overviews) requires the use of a database system. The computing overhead in the evaluation of a solution is much higher than in delivering the problem to the student.

2.3 Comparable systems

Several Internet-based competitions already exist. However, none (of the ones we found) offer the functionality required for the KöMaL competition. Most non-commercial competitions we found are organized by North-American organizations.

- http://www.geschool.org/abacus.html : This is the home page of the ABACUS International Math Challenge. This competition focuses on grades 4 to 8 and enables students to view the exercises (written as HTML pages) on the site. Solutions can be sent in by e-mail, after which they are corrected by the organizer of the competition. This competition has no automated system on its home page and is comparable to the current KöMaL-competition on the Internet.
- http://mathcounts.org : Mathcounts is the American National Mathematics coaching and competition program for seventh and eight grade students. On their home site a problem is published each week. For this problem no real competition exists. Mathcounts is a straightforward non-automated competition which has an interface to the World Wide Web for registering information, just as KöMaL already has. The actual competition is held at competition centers, where teams from schools physically gather on special competition days.
- http://math.uwaterloo.ca/CMC/CMCHome.html : The Canadian Mathematics Competition is a good example of a KöMaL-like competition which also has a home page to publish the answers and results of competition exercises. Again this competition is not an Internet based competition. The real competition is a tournament held in several cities in Canada.
- http://olympiads.win.tue.nl/ioi/ : Also the organization of the International Informatics Olympiad publishes the exercises used in their computing science competition, together with the solutions and other information via a WWW page. Again the real competition is held in annual tournaments in countries all over the world.

From these examples we see that Internet, and in particular World Wide Web, is used as an environment for publishing information concerning exercises, but that no integrated, automated support is offered for the organization of the competition. Existing environments for Web-workflow (e.g., Lotus Domino) and for CSCW [BSCW, DReSS] are not yet well suited for competitions because they lack the support for the many different roles that appear in competitions.

3 Web-CS architecture

To keep Web-CS simple, yet flexible, and to keep the client-part small as well, the system has been designed using off-the-shelf technology. The whole system consists of five parts:

- On the client-side the authentication and the execution of the user's *rights* are controlled by a trusted (signed) Java Applet. This applet communicates directly with a special KöMaL server.
- A standard Web-browser (at present this is Netscape Navigator) hosts the applet.
- A standard Web-server is used to serve information pages and the applet.
- A Java-based special-purpose server translates user requests to database queries and updates.

- All data about users, rights and grades are stored in a relational database. Web-CS uses the freely available PostgreSQL database system [PSQL]. This database system supports JDBC for the communication with the Java-based server part.

3.1 Basic module structure

The basic functionality of the system supports students, evaluators and other users in their typical activities. The requirement that no other software than a browser should be necessary to run the application suggests that each time a user starts the application, e.g. from the competition home page, sufficient software should be made available to enable him to interact with the rest of the system. This part, a Java Applet, is kept small in order to minimize download time. It is a *trusted* or *signed* applet to ensure that it has not been tampered with, and to enable it to access the user's file system.
The Web-CS applet offers a uniform interface for all users. When a user logs in (through the applet) the applet communicates with the database to verify the password and to determine the *rights* of this user. Depending on the role the user plays, different modules (rights) become available to the user. A user, who is unknown to the system, still can view the exercises and high scores, but has no other rights.
The applet is designed in an object-oriented way that corresponds to the different roles a user can play. Known (authorized) users can login directly. Students, who want to join the competition, and teachers are introduced to the system via the school. This introduction is subject to approval by a board member. Board members introduce users, playing other roles, such as designers and correctors. By adding (or removing) rights and some associated code, one can modify the system for competitions with a different organization.

3.2 Document formats and file-uploading

An important design decision for Web-CS is the choice of the document format(s) that can be used for problems and solutions. Because problems and solutions are somewhat similar documents (they deal with the same subject area) and because we want the user-interface to be very similar for all types of users we have opted to use one document format for problems and solutions. Two options were considered:

- It is possible to include a *special-purpose editor* in the Web-CS applet. This has the advantage that all users are automatically ensured to have the same editing environment. Unfortunately this option requires that a user is on-line in order to download and activate the editor from the Web-CS site. Developing a powerful editor-applet takes considerable effort, and the size of the applet would make downloads unacceptably long. For these reasons this option was not selected and implemented.
- A Web-browser can be told to execute a client-side application when receiving a document of a specific *MIME-type*. Web-CS provides one such special MIME-type for both assignments and solutions. All the users of the competition must configure their browser to activate a specific editor, chosen by the editorial board. For the Hungarian KöMaL competition Microsoft Word was chosen because all the secondary schools have PCs with this editor. Other competitions could opt for a different editor that is more suited for their particular audience.

Designers submit assignments to the editorial board. Students submit solutions to assignments. Evaluators submit corrected solutions and grades. To keep the user-interface uniform a single upload mechanism is needed. There are several options for implementing upload mechanisms:

- Use form-based uploading, as supported by most modern Web-browsers. This requires the Web-CS applet to send a request to the browser to first show an appropriate form. The upload is then performed beyond the control of the applet. (Whether the upload is "safe" depends on the use of a secure communication between the browser and Web-server in general. This is possible through SSL.)
- Use e-mail and attachments for uploading. This is not desirable because apart from the solution itself some control information needs to be submitted as well, including the identification of the assignment. Whether the communication is secure depends on the security of the used e-mail program. It is beyond the control of the rest of the Web-CS system.
- Use ftp upload to the server. This is not desirable because it requires duplication of the authorization mechanism. Ftp upload is also not supported by Web-browsers (only ftp download is). Thus, this would require a separate user-interface.

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- Use special upload software on the client, which is activated through a special-purpose MIME-type, just like with the editor. This is not desirable because we do not wish to force users to install any software on their system.
- Implement a special upload protocol within the Web-CS applet. This solution was chosen because it makes it easy to realize a secure communication, which is under the complete control of the applet.

Regarding the security of the communication the current Web-CS architecture leaves two options:

- The Web-CS applet and the Java-based Web-CS server can use the JCE, the Java Cryptography Extension, for encrypting all messages that are exchanged between the applet and the server. This allows for *secure uploads*, but *not for secure downloads*. Indeed, when, e.g., a solution is downloaded by an evaluator, it is downloaded to the Web-browser, using a special MIME-type to activate the client-side editor (which in the case of KöMaL is MS-Word). The download does not pass through the applet, and can thus not be decrypted by it.
- The Web-CS applet can communicate with the Web-server instead of the Web-CS server. The Web-CS server can easily be embedded into the Web-server using Servlet technology. The communication (both ways) between the browser and server can be secured through the SSL protocol (supported by most modern browsers, and by some Web-servers).

The issue of encrypted communication in Web-CS is still under investigation.

4. Current status and Future work

The Web-CS competition system can be tried using Netscape at http://wwwis.win.tue.nl/webcompetitie/. In this prototype only schools can subscribe. The editorial board can perform their supervisory tasks. Students can submit solutions to assignments. Evaluators can get an overview of the solutions they have to correct. They can grade and correct solutions and submit them. The prototype does not yet use encryption. However, because the client-side is entirely based on Java applet technology, the modified client software will be downloaded automatically once it becomes available. The transition to encryption uploads will not be noticed by the existing users.
Two field trials are currently being prepared. In Hungary, the development of the completely Web-based version of the KöMaL competition is continuing. In The Netherlands we are working with the organizers of the International Informatica Olympiad to use Web-CS, e.g., for the pre-selection of candidates for the annual computing science tournaments. Based on feedback from the field trials the user-interface may be updated (probably to give it a more "sleek" look and feel). Also, more ways to generate overviews and reports will be added.
A full version of this paper can be found at http://wwwis.win.tue.nl/webcompetitie/webnet99/.

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